



High Altitude Headache and Acute Mountain Sickness at Moderate Elevations in a Military Population during Battalion-Level Training Exercises

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14. ABSTRACT Few studies have evaluated high altitude headache (HAH) and acute mountain sickness (AMS) in military populations training at moderate altitudes (2000-3000 m). In the current study, researchers interviewed active-duty personnel training at Marine Corps Mountain Warfare Training Center. Participants were asked about HAH and AMS, risk factors, and treatments used. In a sample of 192 Sailors and Marines, 14.6% reported AMS (Lake Louise Criteria) and 28.5% reported HAH. Dehydration and recent arrival at altitude were significant AMS risk factors; dehydration and decreased sleep allowance were significant HAH risk factors. Among AMS-positive participants, ibuprofen users had increased likelihood of reporting threshold AMS than non-ibuprofen users (Fisher's exact test, one-sided, $p < 0.05$). These results suggest that maintenance of hydration and adequate sleep allowance are critical performance requirements at altitude. Further, ibuprofen may be a reasonable treatment for the symptoms of AMS and HAH. Further study is warranted to determine if ibuprofen may be a useful prophylaxis for these conditions.					
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High Altitude Headache and Acute Mountain Sickness at Moderate Elevations in a Military Population During Battalion-Level Training Exercises

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ABSTRACT Few studies have evaluated high altitude headache (HAH) and acute mountain sickness (AMS) in military populations training at moderate (1,500–2,500 m) to high altitudes (>2,500 m). In the current study, researchers interviewed active duty personnel training at Marine Corps Mountain Warfare Training Center. Participants were asked about HAH and AMS symptoms, potential risk factors, and medications used. In a sample of 192 U.S. Navy and Marine Corps personnel, 14.6% reported AMS (Lake Louise Criteria ≥ 3) and 28.6% reported HAH. Dehydration and recent arrival at altitude (defined as data collected on days 2–3) were significantly associated with AMS; decreased sleep allowance was significantly associated with HAH. Although ibuprofen/Motrin users were more likely to screen positive for AMS, among AMS-positive participants, ibuprofen/Motrin users had decreased likelihood of reporting robust AMS relative to non-ibuprofen/Motrin users ($p < 0.01$). These results suggest that maintenance of hydration and adequate sleep allowance may be critical performance requirements at altitude. Further, ibuprofen/Motrin may be a reasonable treatment for the symptoms of AMS and HAH, although further study is warranted.

INTRODUCTION

High altitude headache (HAH) and acute mountain sickness (AMS) are common problems among unacclimatized individuals upon arrival at moderate (1,500–2,500 m) and high altitudes (>2,500 m).^{1–3} In six studies culled from the literature, the incidence of HAH and AMS at 2,000m was 18% and 7 to 28%, respectively; and at altitudes of 3,000 to 3,500m the incidence of HAH and AMS was 10 to 62% and 10 to 28%, respectively.^{1,4–8} Headache ranks among the most common complaints at altitude¹ and precedes the onset of AMS, defined by presence of headache and at least one other symptom: anorexia, fatigue, insomnia, or dizziness after arrival at high altitude.^{5,10} If advanced AMS is unrecognized or left untreated, serious medical problems such as high altitude cerebral edema (HACE) or high altitude pulmonary edema (HAPE) may also arise. Particularly, a diagnosis of HACE often predicts significant morbidity and even mortality, highlighting the practical importance of preventing HAH and AMS at an early stage.^{1–3,11,12}

Strategies for prevention of HAH and AMS typically involve staged ascent, chemoprophylaxis, or both. Low-dose acetazolamide or dexamethasone are medications of choice when medical prevention is necessary for susceptible and high-risk individuals.^{13–17} In two small and one large clinical trial, nonsteroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen/Motrin and aspirin have also shown utility as both treatment and prophylaxis against HAH and AMS.^{18–21} These medications have generated some interest since they may represent a new class of prophylactic agents for AMS that have the added benefit of being widely available over the counter.

As an expeditionary force, the U.S. Marine Corps and its Navy health care components must be able to conduct large-scale training and combat operations in mountainous environments. Because HAH or AMS can demonstrably reduce readiness, the Marine Corps is faced with the reality that fighting an enemy at altitude requires a different level of unit planning, individual readiness, and increased understanding of physiology.^{22–24} Thus, formal doctrine on prevention and treatment strategies is an important practical issue to address for moderate and high altitude training and combat environments.

There is limited military-specific field information that service members can use to guide their preparations and decision-making in a mountainous environment regarding HAH and AMS. Within the past decade, a number of studies have been conducted on military personnel with the aim of either identifying effective acclimatization strategies or assessing physiological predictors of susceptibility at the service member level.^{25–28} Few studies have examined modifiable risk factors for HAH and AMS, such as sleep deprivation or caffeine use, among a military population in a field setting.

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Identification of universal risk factors is important because the rigidity surrounding moderate-to-high altitude military training and operations seldom allows for implementation of preferred acclimatization strategies or exclusion of susceptible subjects. Inadequate data prevent effective doctrine design. Furthermore, most academic field work in the area has focused on Western European or North American populations on business trips, ski vacations, or mountaineering trips.^{5,6,12-15} Challenges faced by U.S. Navy and Marine Corps personnel are categorically different from those seen in a trekking population, including increased physical load, tactical considerations, and operational tempo.²⁹ Moreover, military service members are characterized by a high level of physical fitness, and subject to semiannual physical fitness tests. With the exception of a few field experiments with military samples,³⁰⁻³² most military-based altitude research has been limited to laboratory devices such as a hypobaric chamber, hypoxia tents, or contrived conditions in the field.^{30,33} A more formal understanding of risk factors associated with the development of HAH and AMS among a military population in the field needs to be obtained.³⁴⁻³⁷ An ideal location for such studies is the U.S. Marine Corps Mountain Warfare Training Center (MWTC) near Bridgeport, California. Annually, thousands of military personnel conduct training and field exercises often in preparation for combat deployment, which, in recent years, has included areas where familiarity with mountainous settings is a requirement. The aim of the current study was to obtain preliminary data on prevalence of AMS, HAH, and potential risk factors to determine if there is justification for further field investigations among military populations exposed to moderate altitudes.

METHODS

Aims/Hypotheses

Researchers interviewed active duty Sailors and Marines training at MWTC. Marines were interviewed about HAH and AMS as well as about factors that may have increased or decreased their risk of developing altitude illness or otherwise affected severity. Based on current research, we generated the following hypotheses: (1) prevalence of AMS and HAH will be similar in this Marine population as compared with general trekking populations (10–25% with AMS, using a validated AMS rating scale, and 47–62% with HAH measured using the headache score from a validated AMS rating scale); (2) participants reporting dehydration, decreased sleep, or decreased caffeine/nicotine use will be more likely to report AMS or HAH symptoms; (3) the percentage screening positive for AMS will be greatest on training days (TD) 2 and 3, and least on TD 4 to 6 consistent with the process of acclimatization; and (4) there will be a significant association between ibuprofen/Motrin use and lower scores on a validated AMS rating scale.

Participants

Participants were active duty U.S. Marine Corps or Navy personnel, aged 18 to 35 years old (median age 25 years old), from Camp Pendleton, California, participating in battalion-level military training exercises at MWTC (operational altitudes of 2,000–3,300m [approximately 6,700–10,800 feet]), with most activities falling between 2,400 and 3,300m. Ascent and descent profiles were variable according to the unit to which a given Marine was attached. Because all participants were participating in a rigorous training activity, all were assumed to meet relevant military health and readiness standards necessary for full duty status. Participants had ready access to water and medical care and available interventions against AMS included descent, oxygen, and symptomatic care such as analgesic medications. As a whole, units were briefed on the symptoms of AMS and a separate brief was administered specifically to corpsmen. Before training, the unit medical officer briefed all participants by section before training how to identify signs of dehydration and therefore no definition/criteria needed to be provided on the questionnaire. This is consistent with Marine Corps Order 6200.1E. No acetazolamide or steroid medications were given. The study protocol involved interview procedures, but no links to individually identifiable information or subjects were recorded. This study, approved by the Institutional Review Board at the Naval Health Research Center, was conducted in compliance with relevant federal regulations and local instructions.

Procedure

The majority of potential participants arrived at MWTC the evening before TD 1. Each participant was interviewed only once between TD 2 and 6. The study protocol involved interview procedures that were designed so that they did not interfere with normal training rhythms; the length and content of the survey were done in accordance with the desires of unit leadership.

Researchers sought to make contact by convenience sampling as many members of the battalion as possible regardless of rank or occupation. Participants who were spread across the 46,000-acre-training area were sampled with robust attempts made to contact all members of a given unit. All Sailors and Marines who reported to the Battalion Aid Station (2,040 m) for any reason were screened.

Researchers read to the participant from questions in the screening instrument and marked their responses. The screening instrument contained questions about AMS awareness, AMS symptoms (that day or the previous night), potential risk factors for AMS, ibuprofen (Motrin®) use, and cognitive performance problems. AMS symptoms were evaluated using the Lake Louise Criteria (LLQ) embedded within the research survey. The LLQ is a five-question, self-reported assessment of AMS symptoms. A total LLQ score ≥ 3 (range = 0–15), including headache and at least one other symptom, is diagnostic of AMS. The LLQ is a validated and widely used field

survey tool for evaluating AMS symptomatology in non-military populations.^{3,9,10,36} Questions concerning awareness of AMS symptoms, potential risk factors, ibuprofen use, and cognitive performance problems were dichotomous yes/no responses. If participants had questions about the meaning of any question, researchers rephrased the question and provided an example. Because all participants were briefed by section before training how to identify signs of dehydration, no definition/criteria needed to be provided on the questionnaire. If a participant reported no knowledge of AMS and its symptoms, researchers described the symptoms using the LLQ. Researchers also made note of prior headaches experienced by service members since arrival at altitude, regardless of headache status reported on the LLQ.

Researchers approached potential participants individually at different points during their training exercises. Interview locations were either the Battalion Aid Station or various training locations throughout MWTC. Potential participants were told the nature of the interview and gave their verbal consent. If they agreed to provide feedback, the participants replied to the brief interview and their responses were recorded. No personal identifiers were collected and no identifiable responses were communicated to the training command or battalion leadership personnel. At field locations, participants were reminded they were responsible for seeking treatment for AMS, and that research staff were not tasked with providing treatment.

Statistical Analyses

In compliance with the study protocol, demographic data were not recorded. Frequencies and percentages were used to describe the observed response rates to questions regarding AMS awareness, awareness of a squad member with AMS, occurrence of potential risk factors (decreased sleep allowance, abnormal workload, dehydration, and decreased caffeine/nicotine use), and TD of the interview. Response rates were calculated for all participants, with separate rates for Sailors and Marines screening positive for AMS and HAH.

To evaluate the association of potential risk factors with AMS and HAH, researchers used univariate and multivariate logistic regression to produce adjusted and unadjusted odds ratios (OR). Ibuprofen use was included in univariate and multivariate models because Marines could have used it as a treatment measure for HAH or AMS. A variable for AMS status/severity was created by classifying participants into 3 mutually exclusive categories (no AMS, threshold AMS [LLQ = 3–7], and robust AMS [LLQ > 7]). Similarly, a variable for HAH status/severity with 3 levels was created according to scores reported on the LLQ headache item (no HAH [0], mild/moderate HAH [1–2], and severe HAH [3]). χ^2 tests were used to identify distributional differences between ibuprofen/Motrin users and nonusers with respect to AMS status/severity and HAH status/severity. Fisher's exact test (for small expected cell counts) was employed to evaluate the relationship between receipt of a positive AMS screen and reported awareness of AMS.

Statistical analyses were performed using SAS software, version 9.2 (SAS Institute, Cary, North Carolina). For all statistical testing procedures, two-sided significance was set at the $p < 0.05$ level.

RESULTS

Of the 202 interviews administered, 192 were analyzed. Five interviews were excluded from analyses because of incomplete data. Five were excluded from analyses because the participants had previously been administered the interview. Although specific records were not kept, several Marines declined to participate, mainly as a result of specific high priority duties (i.e., being on watch).

We found 38.5% ($n = 74$) of participants reported HAH a any time since arrival. However, only 28.6% ($n = 55$) reported HAH at the time of interview (Table I). In total, 14.6% ($n = 28$) of participants screened positive for AMS (which was within the hypothesized incidence of 10–25%). There were no emergent cases of severe altitude illness, such as HACE or HAPE.

TABLE I. Response Rates According to AMS and HAH Status Among Marines and Sailors Participating in the Mountain Warrior Course at MWTC, July 2010 ($N = 192$)

	All ($N = 192$), n (%)	AMS ($N = 28$), n (%)	HAH ($N = 55$), n (%)
AMS Awareness	182 (94.79)	24 (85.71)	50 (90.91)
Squad Member With AMS	31 (16.15)	7 (25.00)	14 (25.45)
Allowed Less Sleep	37 (19.27)	8 (28.57)	17 (30.91)
More Work Than Usual	54 (28.13)	9 (32.14)	17 (30.91)
Dehydrated	22 (11.46)	8 (28.57)	11 (20.00)
Use of Ibuprofen/Motrin	43 (22.40)	12 (42.86)	19 (34.55)
Decreased Caffeine or Nicotine Use	83 (43.23)	15 (53.57)	23 (41.82)
TD			
6	46 (23.96)	5 (17.86)	15 (27.27)
5	39 (20.31)	5 (17.86)	7 (12.73)
4	63 (32.81)	8 (28.57)	17 (30.91)
3	35 (18.23)	6 (21.43)	12 (21.82)
2	9 (4.69)	4 (14.29)	4 (7.27)

Univariate and multivariate logistic regression models were created with a positive AMS screen and indication of headache on the LLQ (HAH) as dichotomous outcome variables (Tables II and III). Participants who reported dehydration were more likely to screen positive for AMS (OR = 4.29; 95% confidence interval [CI], 1.60–11.49). The relationship between dehydration and AMS remained significant after adjusting for other potential risk factors (sleep allowance, work load, decreased caffeine/nicotine use, and TD) and ibuprofen/Motrin use (adjusted OR [AOR] = 3.60; 95% CI, 1.22–10.68). Furthermore, the multivariate comparison revealed that participants interviewed on TD 2 or 3 had a significantly greater likelihood of screening for AMS, relative to participants interviewed on TD 4 to 6 (AOR = 3.32; 95% CI, 1.22–9.00). In both adjusted and unadjusted analyses, service members that used ibuprofen had more than 3 times the odds of screening positive for AMS, relative to Marines that refrained from use of ibuprofen (OR = 3.22; 95% CI, 1.38–7.49; AOR = 3.25; 95% CI, 1.30–8.16).

A similar pattern of results emerged for HAH: the univariate analysis showed that dehydration and decreased sleep allowance were significantly associated with self-report of HAH (OR = 2.86; 95% CI, 1.16–7.07 and OR = 2.62; 95%

TABLE II. Adjusted and Unadjusted ORs of Screening Positive for AMS Among Marines and Sailors Participating in the Mountain Warrior Course at MWTC, July 2010 (*N* = 192)

Potential Risk Factor	Univariate		Multivariate	
	OR	95% CI	AOR	95% CI
Allowed Less Sleep	1.86	0.75–4.64	1.56	0.53–4.62
More Work Than Usual	1.25	0.53–2.97	1.26	0.44–3.62
Dehydrated	4.29	1.60–11.49*	3.60	1.22–10.68*
Use of Ibuprofen/Motrin	3.22	1.38–7.49*	3.25	1.30–8.16*
Decreased Caffeine or Nicotine Use	1.63	0.73–3.64	1.94	0.80–4.67
TD				
4–6	1.00		1.00	
2–3	1.60	0.78–3.26	1.92	0.88–4.22

**p* < 0.05.

TABLE III. Adjusted and Unadjusted ORs of Reporting Headache Among Marines Stationed at MWTC, July 2010 (*N* = 192)

Potential Risk Factor	Univariate		Multivariate	
	OR	95% CI	AOR	95% CI
Allowed Less Sleep	2.62	1.25–5.50*	2.61	1.17–5.84*
More Work Than Usual	1.21	0.61–2.40	1.08	0.49–2.34
Dehydrated	2.86	1.16–7.07*	2.31	0.88–6.04
Use of Ibuprofen/Motrin	2.49	1.22–5.05*	2.57	1.21–5.48*
Decreased Caffeine or Nicotine Use	1.63	0.49–1.74	0.94	0.48–1.85
TD				
4–6	1.00		1.00	
2–3	1.60	0.78–3.26	1.92	0.88–4.22

**p* < 0.05.

TABLE IV. AMS Screening Results and Headache Reporting According to Ibuprofen/Motrin use for Marines Participating in the MWTC Mountain Warrior Course July 2010 (*N* = 192)

Potential Risk Factor	Use of Ibuprofen/Motrin		<i>p</i> -Value
	Yes, n(%)	No, n(%)	
No AMS	31 (72.09)	133 (89.26)	2.61
Threshold AMS (LLQ = 3–7)	12 (27.91)	11 (7.38)	1.08
Robust AMS (LLQ > 7)	0 (0.00)	5 (3.36)	2.31
No HAH	24 (55.81)	113 (75.84)	2.57
Mild/Moderate HAH (1–2)	18 (41.86)	34 (22.82)	0.94
Severe HAH (3)	1 (2.33)	2 (1.34)	
Total	43	149	1.00

CI, 1.25–5.50, respectively). After adjustment, decreased sleep allowance remained significantly associated with HAH (OR = 2.61; 95% CI, 1.17–5.84). In both adjusted and unadjusted analyses, self-reported use of ibuprofen/Motrin more than doubled the odds of reporting HAH (OR = 2.49; 95% CI, 1.22–5.05; AOR = 2.57; 95% CI, 1.21–5.48). TD was not found to be significantly associated with HAH prevalence.

χ^2 tests were conducted to examine the association between ibuprofen/Motrin use and both AMS status/severity and HAH status/severity (Table IV). Although 12 (27.9%) of the 43 participants that reported ibuprofen/Motrin use screened positive for AMS, no members of this population qualified for robust AMS. The distribution of AMS screening results was significantly different among participants that did not take ibuprofen/Motrin, with a lower percentage screening positive for AMS (10.7%), but a higher percentage suffering from robust AMS (3.4%) (*p* value < 0.01). Distributional differences were also observed when comparing HAH status/severity between participants who did and did not report ibuprofen use (*p* value = 0.04). Forty-four percent of Marines who used ibuprofen reported a headache of any severity, relative to only 24% of Marines who did not use ibuprofen. Relatively few participants reported severe headache (*n* = 3).

The overall percentage of participants reporting awareness of AMS symptoms was high (94.8%). Of the 10 participants who reported a lack of awareness, 4 (40%) screened positive for AMS relative to only 13.2% of those who were aware of symptoms (exact *p* value = 0.04). Of the participants, 16.2% (*n* = 31) reported knowing a squad member who was displaying AMS symptoms (Table I).

DISCUSSION

AMS and HAH are well-recognized conditions that affect people at various altitudes around the world. Isolated HAH is generally regarded as a precursor of AMS, and it is important to conceptualize the idea that factors that may trigger headaches will very likely increase vulnerability to AMS.

Our study evaluated a military population performing field exercises at moderate (1,500–2,500 m) and high (>2,500 m) altitudes. Consistent with predictions, AMS was observed at approximately the expected prevalence compared with

recreational populations. As expected, the potential risk factors dehydration and recent arrival at altitude (defined as data collected on days 2–3) were significantly associated with AMS. Also, among AMS-positive participants, ibuprofen users were less likely than non-ibuprofen users to report robust AMS. The prevalence of HAH was modestly below expectations. Decreased sleep allowance was significantly associated with HAH. Interestingly and contrary to expectations, neither recent arrival at altitude nor dehydration were significantly associated with HAH in the adjusted model. HAH was significantly associated with use of ibuprofen. Within a military sample, these are all novel and potentially useful findings.

Increased understanding of AMS and HAH prevalence rates in a military population enhances military-centered research programs and aids future studies. However, it is important to remember that these results have their limitations. A variety of outside factors influenced these findings; changing one factor could lead to increases or decreases in AMS and HAH prevalence. A factor that may have contributed to the prevalence of AMS and HAH in the current study was maximum altitude attained (3,300 m). Previous studies have shown that maximum altitude plays an important role in determining severity of altitude illnesses such as AMS and HAH. With aims similar to ours, a study conducted in Nepal found that AMS prevalence rate increased by 10% at an altitude between 3,000 and 4,000 m, 15% between 4,000 and 4,500 m, 51% between 4,500 and 5,000 m, and 34% over 5,000 m.³⁸ Similarly, participant education about AMS may have affected HAH and AMS prevalence: approximately 95% of participants reported knowledge of AMS. The results presented here are consistent with past research showing that AMS education may reduce the likelihood of developing AMS.³⁹ Although various outside factors such as maximum altitude could certainly have influenced AMS and HAH prevalence, significant individual risk factors are also likely to have modulated prevalence.

As expected, dehydration was significantly associated with AMS. In normobaric hypoxia modeling of AMS, dehydration significantly increased AMS severity.^{40,41} Recent arrival at altitude was also significantly associated with AMS, which closely mirrors previous findings.^{1,2,6} In addition to the significant relationships, the current study was somewhat consistent with respect to nonsignificant findings (e.g., decreased stimulant use was not associated with AMS or HAH). Also consistent with our findings, in a study of recreational trekkers in Nepal, researchers found no relationship between smoking and AMS vulnerability.³⁷ One interesting finding was the relationship between decreased sleep allowance (sleep restriction) and HAH. However, the finding that sleep restriction triggers headache is relatively robust and therefore can be discounted as novel.⁴²

Among study participants, ibuprofen users were less likely to report robust AMS than non-ibuprofen users. The cross-sectional nature of this study did not allow for the evaluation

of treatment effects. Nevertheless, by demonstrating a relationship between ibuprofen use and AMS severity in a military population, these findings contribute to the body of clinical evidence supporting ibuprofen's effectiveness at reducing AMS symptoms. The use of various NSAIDs like ibuprofen has been proposed as a treatment for HAH and AMS, and confirmed in a prospective, double-blind clinical study to be as effective in reducing HAH as acetazolamide.²¹ Mechanistically, ibuprofen via cyclooxygenase inhibition prevents the production of prostaglandins and the inflammatory cascade, chemical irritants known to sensitize meningeal receptors that mediate nociception.^{43–45} Although multiple studies show the NSAIDs ibuprofen and aspirin to be effective prophylactic agents against HAH and AMS, some studies are not supportive in this regard. Two studies have suggested the related NSAIDs naproxen and calcium carbasalate are ineffective for prevention of AMS (Although it is important to note that these studies were observed to have significant methodologic issues).^{46,47} Furthermore, it remains unclear whether NSAIDs address the underlying pathology of HAH and AMS, or alternatively work via a simple analgesic effect. That said, these findings provide further evidence that ibuprofen, an over-the-counter NSAID, may be effective as an AMS treatment. For both AMS and HAH, the use of ibuprofen was higher among participants screening positive relative to those screening negative. These findings suggest that elective use of ibuprofen to treat altitude illness may have occurred within this population of Sailors and Marines. The cross-sectional assessment of both AMS status and ibuprofen use, however, does not allow for the confident identification of ibuprofen as a treatment measure and this hypothesis is deserving of further study.

Collectively, these individual risk factors associated with HAH and AMS are consistent with previous literature, making the results largely confirmatory. However, because this was a preliminary investigation, confirming previous findings are of great importance. Furthermore, finding consistent results across studies is important for the development of generalizable scientific knowledge.

This preliminary investigation had strengths and weaknesses. The primary limitation in this study relates to the fact that it was a cross-sectional, convenience sample, and therefore we were unable to evaluate risk. Results were necessarily limited to the identification of significant associations between potential risk factors and probable outcomes. Secondary limitations were that age was not collected and that no information on headache history was collected as younger individuals and those that self-report experiencing frequent headaches in daily life report more severe headaches related to AMS.⁴⁸ Therefore, conclusions could not be discussed in terms of causation. Future studies involving military populations should use a longitudinal approach in order to obtain information about the incidence of altitude illness and factors influencing disease risk. Furthermore, demographic information and health histories were not collected, which

precluded investigation of additional factors that might have been associated with AMS or HAH prevalence (i.e., pre-existing medical conditions).

As a point of caution, with military samples, there is often a Spartan attitude that operational concerns outweigh the individual's needs.²⁹ This mindset could have resulted in underreporting AMS and HAH. Some Marines/Sailors may have avoided medical evaluation and treatment, even in the presence of disease, because they wished to remain in the training. Attempts such as these would have resulted in underreporting of symptoms and attenuation of power to discern significant associations. Nevertheless, significant results were identified with reason to believe the type I error rate remained intact ($\alpha = 0.05$). Explaining symptomatology to an individual participant might have injected nonsystematic bias. However, given that over 94% of participants reported AMS awareness, this bias is unlikely to have played a significant role.

Future studies of AMS and HAH within military populations operating at moderate and high altitudes are needed. Studies should evaluate the physiology behind HAH and AMS and identify possible objective physiological markers. Some researches have been performed, focusing primarily on the relationship between signs of physiological stress, levels of various blood markers like hematocrit, hemoglobin, blood lactate, and blood glucose, and AMS symptoms.⁴⁹ Measurement of intracranial pressure using the optical nerve sheath holds promise for future work.⁵⁰ Future work should incorporate studies in a controlled environment simulating high altitude and focusing on understanding the evolution of physiological markers of AMS. Understanding the physiology of AMS should address whether factors such as sleep deprivation or migraine history be seen as independent causes of headache that lead to false diagnoses of AMS or should these factors be seen as factors that increase risk of AMS. In turn, this would lead to clarification as to whether NSAIDs can treat AMS in addition to nonaltitude related headaches.

Finally, given the finding that ibuprofen use is associated with reduced AMS severity, a pertinent research study would be to evaluate the efficacy of NSAIDs such as ibuprofen as means of reducing HAH and AMS in operational-like environments such as MWTC. Building on prior research efforts in other labs,^{33–35,37} assessments should include brief physiological measures such as respiratory rate, heart rate variability, blood oxygen and carbon dioxide saturation levels, saliva, and blood samples for presence of inflammatory biomarkers that may substantiate the use of NSAIDs in the treatment and/or prevention of altitude illness.

CONCLUSIONS

The current study found that potential risk factors such as dehydration and recent arrival at altitude were significantly associated with AMS, whereas decreased sleep allowance was significantly associated with HAH. Among study participants, self-reported use of ibuprofen was associated with less robust

AMS. Simple management of hydration and sleep could potentially reduce symptoms and increase readiness and performance. Studies in military populations will assist with the development of surveillance tools that will inform planning and operational medical intelligence. Importantly, future research can determine whether military clinicians should consider ibuprofen an effective treatment and/or prophylaxis against AMS. This readily available nonprescription medication could potentially be a simple means of reducing symptoms experienced at altitude.

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